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Pacific Salmon in New Zealand

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Abstract

Oncorhynchus tshawytscha has a normal anadromous habit, and runs in most of the snow-fed rivers on the east coast of the South Island. Anatomical investigation reveals a lower number of vertebrae than is recorded for American stocks, while the number of pyloric caeca agrees well with that of fish from the Sacramento River. *Oncorhynchus nerka* is known only from Lake Ohau, which is cut off from free communication with the sea by a power dam, and where it appears to have established a self-supporting freshwater colony of dwarf fish.

Two species of Pacific salmon are known to exist in New Zealand, *Oncorhynchus tshawytscha,* known in this country as the quinnat and *Oncorhynchus nerka,* the sockeye. They have not been equally successful in establishment, and their habits and life history differ considerably. Significant changes in the growth rate and abundance of quinnat have occurred recently.

Oncorhynchus tshawytscha

The first importation of quinnat eggs recorded by Thomson (1922) was made by the Auckland Acclimatisation Society in 1875, and up till 1880 about 430,000 live eggs had been procured by this and other acclimatisation societies and the New Zealand Government. These eggs would be from the McCloud River according to particulars given me by Dr John C. Briggs, assistant Professor, University of British Columbia, who has specialised in the older literature on the subject. Referring to the dates mentioned above (1875–1880) Dr Briggs states in a letter dated March 20, 1961, "This information fits in well with the Reports of the U.S. Fish Commission covering the same period of time. Large numbers of eggs were taken at a government hatchery on the McCloud River, a tributary of the Sacramento River in California. Mention is made in several places of shipments to New Zealand." Some of the eggs imported at this time appear to have been planted in streams and others are recorded as having been hatched and the young fish liberated either as fry or after a period spent in rearing ponds. The principal rivers receiving substantial quantities of eggs or fish were the Waikato, Thames and Mangakahia in the North Island, and the Oreti, Rangitata, Rakaia, Waimakariri and Hurunui in the South Island.

After a period during which no importations were made a project of intensive stocking of one locality was undertaken, shipments of from 300,000 to 500,000 eggs being obtained each year from 1900 to 1907 and the fry derived from them liber-

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ated in tributaries of the Waitaki River. The late L. F. Ayson, Chief Inspector of Fisheries, recorded in 1924 that the 300,000 eggs obtained in 1900 were supplied by the United States Bureau of Fisheries from its salmon station on the McCloud River at Baird, California, but did not state the place of origin of later shipments. The first adult fish recognised in the Waitaki basin was taken in 1905, and in 1907 fish were running in the Hakataramea, a tributary of the Waitaki, in sufficient numbers to provide 50,000 eggs for the hatchery operated on this stream. The stripping of local fish was continued, and greater numbers of eggs were obtained each year until in 1923 the total had risen to 1,510,000. These were allotted to the Wairau River (600,000), Hokitika River (400,000), Upper Clutha (200,000), Queenstown hatchery, Lake Wakatipu, also in the Clutha drainage (150,000), Tasmanian Government (100,000), and the balance retained at Hakataramea. The distribution of eggs on a large scale continued till about 1940.

Whether the fish was acclimatised solely by the concentrated stocking of the Waitaki commenced in 1900 or was already established in New Zealand waters at that time is an open question. There appears to be no doubt that the Waitaki liberations produced results, but there can be no certainty that a wild stock derived from earlier liberations was not in existence when the Waitaki project was started. Considerable quantities of fry had been liberated in four of the principal quinnat rivers of Canterbury—namely, the Rangitata, the Rakaia, the Waimakariri and the Hurunui, and while the first fish that can be regarded as having been satisfactorily identified came from a tributary of the Waitaki, this may have been owing to attention being concentrated on this water as a result of the extensive stocking project in progress there. Few people in New Zealand were capable of recognising a quinnat, thousands of which could have passed up such a river as the Rakaia and been mistaken for large brown trout. As a result no evidence of spread along the coast and progressive appearance in different rivers is available. When the fish came to be better known it was found to be running in all glacial or snow-fed rivers from the Clutha (46deg south latitude) to the Waiau-ua (43deg). These limits do not appear to have been transgressed, so far as the occurrence of well defined runs is concerned, but stragglers have been taken occasionally in many localities. For some years about 1950 small fish about 7lb in weight were taken in Westland, principally from a stream flowing into the Okarito Lagoon. The scales indicated stunted growth, and it seemed unlikely the run would continue. The absence of the fish from the Waiau River in Southland appears to be owing to the physical features of this water. Although one of the largest rivers in the country and located to the south of the Clutha, it does not carry the proportion of glacial water that the Clutha does but is fed principally by the drainage of extensive forests.

In the early years of establishment of the fish in New Zealand the spawning migration into the rivers appears to have commenced in February and to have continued to the end of March, the peak of the run being about the middle of March. More recently the run has commenced in January, and in the 1960-61 season the first fish were taken in the Rakaia River on December 9. Some of the fish proceed upstream as far as shingle suitable for spawning extends and others travel only short distances. Dark fish that have been in the river for some weeks and appear to be waiting to spawn in the immediate vicinity may be found throughout the shingly part of the rivers from a few miles above the sea. Spawning occurs in April and May, and the smolts go down to the sea in considerable numbers during March and April. A group of 30 taken in March from shingly shallows in the Waimakariri River had an average length of 95 mm. Their stomachs were full of minute adult Diptera.

The scales of these smolts agree well with the parr section of the scales of most adult fish. In such fish the period of river-life is actually a month or two less than one year, and it is not always clear on the adult scale where the complete year ends. The parr structure sometimes merges into the more open sea-formed structure, and in scales showing a positive demarcation it is not always possible to determine whether this represents the completion of the twelve months of life, the time of migration or the coincidence of these two influences.

Several seasons about 1927 were noteworthy on account of the large number of fish coming in from the sea that carried fresh injuries, apparently teeth marks of some unknown predator. These gradually became less numerous, and in about ten years injured fish were seldom seen. Recently, injured fish have become rather more numerous, the proportion observed in 1962 being about 10 per cent.

STRUCTURAL FEATURES

Particulars of structure are given to define the type of fish existing here, and so enable comparisons to be made with American stocks. Data on the principal meristic characters of 15 specimens taken from 1927 to 1949 are presented in Table I, and a general description based on these data supplemented by less complete records of other specimens, and including particulars of other characters is appended. The longitudinal count of scales was made actually in the lateral line and was continued as far back as the scale covering extends. All vertebrae having a definite joint at each end have been counted. The anterior joint of the first vertebra is not a flexible one, and several upwardly deflected vertebrae are embodied in the hypural. These are counted as far back as the last visible joint, the terminal bone beyond this being omitted. The averages for the branched rays in the dorsal and anal fins and the averages in several other numerical characters are given in parenthesis after the record of maximum and minimum values.

The abbreviations used in the table stand for branchiostegals, dorsal fin rays, anal fin rays, scales in lateral line, gill rakers, vertebrae and pyloric caeca.

TABLE I.—MERISTIC CHARACTERS OF 15 SPECIMENS FROM THE RAKAIA AND WAIMAKARIRI RIVERS.

B.	D.	A.	L. Lat	G.R.	Vert.	Caeca
15–17	iv 10	iii 16	130–131	26–26	63	144
16–17	iv 10	iii 15	130–130	23–25	65	218
15–15	v 10	iii 16	130–132	24–26	64	149
16–18	v 10	iii 15	134–135	25–25	64	198
13–15	iv 10		126–127	22–22	63	137
15–16	iv 10	iii 16	131–132	24–27	62	193
16–17	iv 10	iii 14	136–137	26–27	63	171
15–16	v 10	iv 14	132–132	24–24	65	167
14–16	iv 9	iv 13	134–136	24–24	65	151
16–16	v 10	iv 14	131–132	25–26	63	166
15–16	v 10	iii 15	130–131	26–27	65	157
16–18	iv 10	iv 15	131–131	24–25	63	172
17–17	iv 11	iv 14	130–130	25–27	62	154
15–16		iv 14	128–128	24–24	63	191
15–16	iv 10	iii 15	130–130	25–25	62	135

Oncorhynchus tshawytscha

B. 14–18 (16). D. iv–v 9–11 (10). A. iii–iv 13–16 (14.5)

Number of scales in lateral line 128–137 (131.5), vomer usually toothless but occasionally with a few weak teeth on its head. Gill rakers on anterior gill arch 23–27 (25), pyloric caeca 135–218 (172.5), vertebrae 62–65 (63.3).

Head .226–.256 of standard length, maxillary extending well beyond the eye, narrow, sinuous, posteriorly in large specimens. Dorsal fin inserted at .47–.49, ventrals at .52–.55 of standard length. Least depth of caudal peduncle .475–.625 of peduncle length, its length .134–.153 of standard length. Caudal fin moderately emarginate.

Maximum total length observed 42 inches.

No comprehensive account of the morphology of any of the various stocks existing in North America is available for comparison, but data on certain characters are given by Dr W. E. Ricker in an extensive consideration of evidence for environmental and genetic influences on certain characters which distinguish stocks of the Pacific Salmons and steelhead trout. This is in the form of a cyclostyled manuscript, and does not appear to have been published in the regular way but has been widely circulated among scientists studying salmon in Canada and the United States, and others. References to all works from which evidence has been drawn are given by Dr Ricker, and when this evidence is quoted here the accompanying reference includes the words "per Ricker, 1959".

Seymour (1959, per Ricker 1959) carried out experiments by rearing eggs from one pair of fish at different constant temperatures and found that the number of vertebrae is least at normal temperatures and higher at lower and higher temperatures. The mean values for young fish reared at intermediate temperatures from eggs from four localities are copied in the following table, which also gives the mean of the 20 New Zealand fish used in the present investigation.

Table 2.—COMPARISON OF VERTEBRAL COUNTS

System or Region	Tributary	Mean No. of Vertebrae
Sacramento		66.39
Columbia	Entiat	71.73
Puget Sound	Green	69.57
Puget Sound	Skagit	68.36
New Zealand	Rakaia and Waimakariri	63.3

The difference between the American and New Zealand figures is so great as to lay the validity of the comparisons open to question. If the American counts included the urostyle, which must be recognised as a possibility, this would have been responsible for a difference of only one, and the difference would still be greater than could be expected to occur in any sets of data obtained from the same species. The American counts were made on young fish hatched within the normal temperature range, and which could be expected to be representative of the normal stock, but whether the young fish were sufficiently grown for accurate counting is not known. Under these circumstances the comparison must be regarded as of doubtful value.

FIG. 1

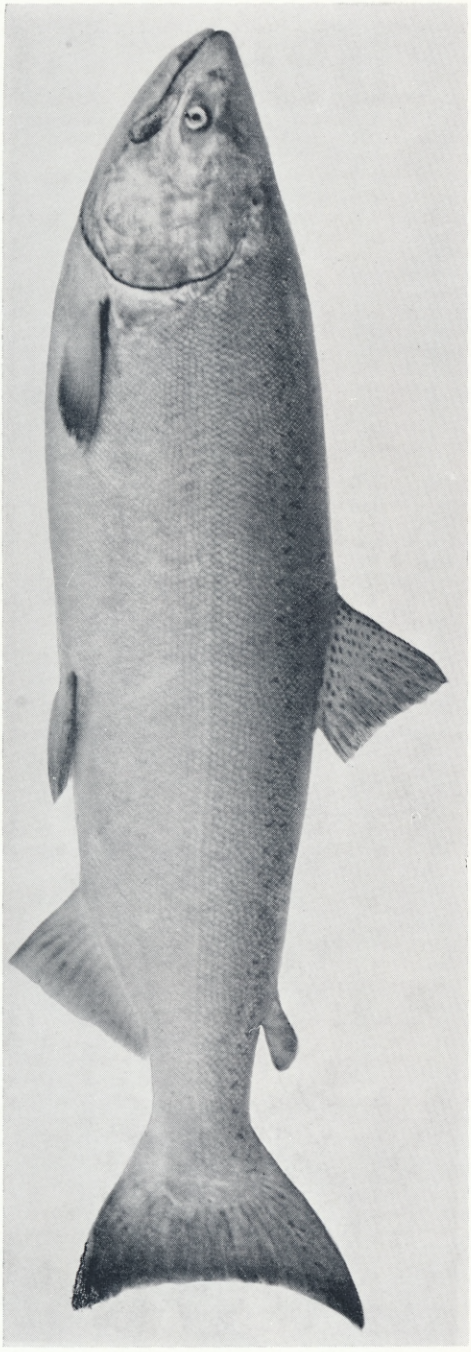

FIG. 2

FIG. 1.—Sea-run *Oncorhynchus tshawytscha* 34 inches. Rakaia River.

FIG. 2.—Lake-dwelling *Oncorhynchus nerka*. Mature male, 11¾ inches. Lake Ohau. April, 1961.

More definite data are given on the number of pyloric caeca by McGregor (1923, per Ricker, 1959). The counts appear to have been made on mature fish trapped on their spawning migration, and to be directly comparable with the New Zealand figures presented herewith.

TABLE 3.—*NUMBER OF PYLORIC CAECA.*

Locality	Minimum	Maximum	Mean
Sacramento	134	214	176
Klamath	93	193	133.2
New Zealand	135	218	172.5

This is the first evidence of affinity of the New Zealand fish with the Sacramento stock. The numbers agree as closely as would be expected if two such groups had been taken from a single locality. The number of caeca appears to be one of the characters least affected by influences such as environment and age in various salmonoids that have been investigated. The group of 30 quinnat smolts from the Waimakariri River, already referred to in the present paper, had an average of 173.5 caeca, which comes within one of the average for adult fish.

About 1957 a decline in the size and growth rate of quinnat occurred. When this became evident it was noticed that the number of anal fin rays of the few fish examined intact was below normal. In 1961 it was possible to examine 28 specimens taken at the Rakaia, and to compare the results with records of 20 specimens counted from 1927 to 1949. Counting only developed rays (all the branched rays plus one simple ray) the averages were 15.5 for the 1927–49 collection and 15 for 1961. The difference is not great but assumes some significance when the frequency with which the different numbers occur is considered. This is shown in Table 4.

TABLE 4.—FREQUENCY DISTRIBUTION OF DEVELOPED RAYS IN ANAL FIN.

Date	Number of Specimens	Number of Rays 12	13	14	15	16	17
1927–49	20		1	1	8	7	3
1961	28	1		5	15	6	1

Whereas the numbers 15 and 16 are almost equally distributed in the 1927-49 collection there is a definite peak at 15 in the 1961 group. Seymour (1959, per Ricker, 1959) in the experiment mentioned when dealing with vertebrae, found that the number of anal fin rays was greatest in fish hatched at normal temperatures and lower in fish hatched at higher and lower temperatures. While the number of vertebrae was increased by extreme temperatures and the number of anal fin rays was reduced, the significant circumstance is that, in each character a change in either direction produced the same result. This change appears to be merely a reaction to unsuitable conditions analagous to that which sometimes precedes the extinction of an organism. It is quite likely that changes of the same nature would be brought about by other detrimental influences such as unsuitable chemical constitution of the hatching water, or deteriorated condition of the parent fish.

Lake Dwelling Quinnat

Many upland lakes in the drainage basins of rivers receiving runs of quinnat from the sea carry small fish that spend the whole of their lives in fresh water. Some of these lakes, such as Lake Sumner and Lake Heron, are in open communication with the sea, and the freshwater residence of the fish is entirely voluntary. Lake Wanaka and Lake Hawea were in the same category until 1956, when the Roxburgh power dam was established in the Clutha River, which drained them. There is one lake, Lake Coleridge, in which the freshwater residence of the fish is not voluntary. In its original state this lake had only a small outlet, which was closed when the Coleridge electric power station was established in 1914. In 1920 the Harper River, an alpine stream of considerable size flowing into the Wilberforce, a tributary of the Rakaia, was diverted into Lake Coleridge to augment the water supply for the power station. A channel was cut to the outlet end of the lake, and the old course of the Harper was stopped off with a non permanent dam which provides a means of safety by washing out during dangerous floods and allowing the surplus water to flow down the old channel. If the river is in this state during the run of quinnat in the Rakaia, fish going up the Wilberforce may enter the Harper and run up past the diversion works to the upper waters. When the smolts derived from the spawning of these fish descend the river the old course may be stopped off, leaving no course open to them except the diversion channel into the lake. In the event of the dam being washed out two streams would be available to the smolts, and at least some of them could be expected to go down the lake channel.

This lake produces the largest freshwater quinnat in New Zealand, and is the only one where lake-grown fish are known to have reproduced. When these fish were first investigated in 1931 they ranged from 4lb to 6½lb in weight and from 23 inches to 26½ inches in length, and averaged 5.3lb and 24.6 inches. The gonads were normal and many fish spawned in the Harper and its tributaries, the Ryton, the Scammander and the Simois. After spawning the fish died in the normal manner, so far as is known. The next season quinnat were very scarce at Lake Coleridge, and all those observed were from 7lb to 9lb in weight and from 28in to 31½in in length. These were fourth year fish of the same birth year as the 23–26½ inch specimens that were so abundant in the previous season. The scales of these fourth year fish had a distinctive feature in the form of a definite band formed at the winter preceding maturity. The inner part of the scale was indefinite, and corresponded to the whole scale of the third year fish taken the previous year. (Stokell, 1934, p. 271, figs. 5 and 6). The following season was also a poor one, a few fish of about 7lb being taken together with some of medium size and other very small ones, about 1lb in weight. In the 1933–34 season quinnat were extremely plentiful in Lake Coleridge. On November 26 about 70 that had been taken by anglers in two days were observed at the Harper end of the lake. They ranged from about 2lb to 3lb in weight and from 16 inches to 22 inches in length, with respective averages of 2.59lb and 19.70 inches. Large quantities of fish of similar size and condition were reported from several other parts of the lake. These fish revealed subnormal development of the gonads associated with progressive deterioration. As the season advanced the eggs of females became shrunken and adhered together in degenerate masses. None of those observed was capable of spawning. The scales of this group were better defined than those of the first batch observed, and showed the fish to be in their third year. These fish were obviously the offspring of the lake-grown fish which spawned abundantly in the winter of 1931, and appear to have reached the limit of freshwater existence.

In 1931 and 1932 the viscera, scales and data of 19 freshwater quinnat were obtained from Lake Wanaka, which was then in open communication with the sea. At that time considerable numbers of sea-grown quinnat ran up the Clutha River to this and other lakes within its drainage basin, and spawned in their head tributaries. The collection comprised fish of from 1.25lb to 2.5lb in weight and from 15 inches to 20 inches in length. The average weight and length were 1.68lb and 18.10 inches respectively. These fish had decadent gonads similar to those of the second Coleridge generation and, so far as the material examined is concerned, would never have spawned. Whether they belonged to a first or second freshwater generation is not certain, but it is to be noted that similar specimens were taken in the two seasons and that nothing approaching the size and development of the first Coleridge generation was obtained. The difference between the Wanaka and Coleridge fish is that the former were voluntarily freshwater dwelling while the latter are effectively confined by the arrangement of the diversion channels. The Wanaka fish were, or had been, derived from aberrant individuals in which the instinct to migrate to sea had been lost, as in the progenitors of the freshwater-dwelling *Salmo salar* of Lake Te Anau. At Lake Te Anau the aberrant individuals of *Salmo salar* were able to establish a regenerative stock in fresh water (Stokell, 1959) but no instance of reproduction is known in quinnat that had access to the sea, and failed to avail themselves of it. Small freshwater quinnat are taken occasionally in the upper Waitaki basin, which was isolated from the lower part of the river by a power dam constructed in 1934, but two specimens examined in 1955 proved to be old stunted fish incapable of ever spawning. The deterioration of these fish is consistent with derivation from freshwater parents, but if they were so it would not necessarily imply that such parents were similarly derived. It is a common practice of acclimatisation societies to salvage trout fry from small streams that are in danger of drying up and transfer them to permanent water. Many quite small trout streams contain quinnat fry which would not be distinguishable from trout fry and could gain access to the waters above the dam in this manner. While the possibility of a self-supporting freshwater colony being established must be recognised, it is necessary to emphasise that there is no definite evidence in support of such a happening and much against it. The only locality where reproduction of freshwater quinnat is known to occur is Lake Coleridge, where the stock is frequently renewed by incursions of smolts bred from sea-run fish in the Harper River.

Oncorhynchus nerka

The only importation of eggs of this fish recorded by Thomson (1922) was in 1902, when a shipment of 500,000 was sent from Canada to New Zealand via San Francisco. The eggs are said to have arrived in bad condition and only 116,200 fry to have hatched, of which 5,000 were liberated in tributaries of the Waitaki, 91,200 in head tributaries of Lake Ohau and 20,000 retained in hatchery ponds. These, with the exception of a small number lost, were liberated in the Hakataramea at various ages from eleven months to five years. All of these waters are in the basin of the Waitaki, which has the most extensive alpine drainage and carries the greatest quantity of glacial water of all the New Zealand rivers. In 1907 four fish having the following data: Male, 19 inches, 42ozs; male, 18 inches, 36ozs; female, 28 inches, 28ozs; female, 23 inches, 23ozs were taken from Lake Ohau and sent to Sir James Hector, who determined them as young, sea-run sockeye. In his report, quoted by Thomson, he stated that if these fish had been allowed to mature they might have produced about 2,000 fertile eggs, from which it would appear that they had not spawned, despite

their very poor condition. A few other sea-run sockeye are recorded as having been taken in the Hakataramea and Twizel Rivers, but reports of captures ceased in a few years and the fish was regarded as having adopted a freshwater existence in Lake Ohau. In 1929 three specimens of these lake-dwelling fish were obtained from Mr. C. L. Ayson, manager of the Hakataramea hatchery. They ranged in length from 7.25 inches to 8.25 inches and all were males almost ripe for spawning. Brief specifications of these fish are: Branchiostegals 11–15, Dorsal fin (developed rays) 11, Anal fin (developed rays) 13–15, gill rakers on anterior arch 33–36, pyloric caeca 88–92. In colour they were whitish below, pale greyish on the sides and greenish grey with small scattered black spots on the back. While the counts confirmed the identity of the fish as *Oncorhynchus nerka* the other circumstances seemed to lay the hypothesis of permanent freshwater existence open to question. These fish agreed closely in size, colour and the preponderance of males with the aberrant offspring of sea-run parents recorded by Ricker (1938) as remaining in North American lakes when the majority of the young fish migrate to sea. It is further to be noted that the Lake Ohau specimens differed from the lacustrine form known as kokanee, and sometimes regarded as the subspecies *Oncorhynchus nerka kennerlyi*, which has equal representation of the sexes, produces successive generations in fresh water, and assumes a bright red colouring at spawning time. The circumstances were consistent with the occurrence of an undetected run of sea-grown sockeye in the Waitaki at the time, but whether this existed or not is not likely to be ascertained now.

In 1934 the lakes and tributary streams in the Waitaki basin above the Hakataramea were cut off from communication with the sea by the construction of a power dam at Kurow. A fish pass was incorporated in the structure but it was of unsuitable design, and it was demolished in 1954 when alterations to the dam were being made. Reports of small sockeye in Lake Ohau and in the ponded water above the dam were current for many years, but specimens received from time to time proved to be *Oncorhynchus tshawytscha* or *Salmo trutta*; and these two species and *Salmo gairdneri* were the only introduced fishes obtained during several collecting expeditions to Lake Ohau. It was April, 1955, before any further evidence of the existence of another salmonoid in these waters was obtained. At that time while I was collecting with Mr P. Bayn, manager of Huxley Station, in small streams about seven miles above Lake Ohau, bones and other fragments of small fishes were obtained under conditions suggesting that the fish had been hauled out of the water and partly eaten by hawks or other birds. These fragments included a gill arch with 33 gill rakers and a vomer with the body carrying teeth, three wide in one place. On March 23, 1961, I obtained from Mr H. B. L. Johnstone, president of the Waitaki Acclimatisation Society, two frozen specimens which had been taken by Mr Bayn in head tributaries of Lake Ohau about a week previously and sent down for transmission to me. Particulars of these fish are given in Table 5, all dimensions being recorded in millimeters. The caeca were in bad condition, and it is certain that a few extra had existed in each specimen, and the scale counts are doubtful as a result of severe erosion and a considerable development of tough spongy skin. No. 1 specimen is a fully mature male and No. 2 a female carrying fully developed eggs 5.70 to 6.50 mm in diameter. No distortion of the jaws was present and there was no enlargement of the teeth in them. In each specimen the vomer carried teeth along about three-quarters of the body, but none on the head. They exhibited no difference in colouring, both being whitish below, pale grey on the sides and greenish grey with a few small black spots posteriorly on the back.

TABLE 5.—MEASUREMENTS AND COUNTS OF TWO SPECIMENS OF *ONCORHYNCHUS NERKA* FROM TRIBUTARIES OF LAKE OHAU.

	1	2
Total length	298	267
Standard length	268	238
Head	73	55
Eye	13	13
Snout	21.5	12
Rear of eye	34	23
Rear of maxillary	36.5	21
Dorsal fin origin	136	115
Ventral fin origin	141	125
Length of pectoral	51	45.5
Length of ventral	37	33
Height of anal	29	30.5
Length caudal peduncle	38	34.5
Least depth of peduncle	23.5	21
B.	13–14	13–13
D. developed rays	10	10
A. developed rays	14	14
Scales, lat.	133	139
Scales, above line	24	22
Scales, below line	33	31
Scales, adipose series	14	13
Gill rakers	33–34	33–33
Pyloric caeca	71	65
Vertebrae	65	64

In the absence of measurements of normal sea-grown sockeye it is not possible to test the present fish for proportional change of the characters that proved most affected by a lacustrine existence in *Salmo salar* and *Oncorhynchus tshawytscha*. These were the length of the head in relation to the standard length, the length of the caudal peduncle in relation to the standard length and the depth of the peduncle in relation to its length. The values for the present specimens are given below together with the proportions for sea quinnat and lake-grown quinnat given in the previous work (Stokell, 1959).

TABLE 6.

	Head is of S.L.	Peduncle is of S.L.	Ped. depth-length
Ohau sockeye	.254	.144	.613
Lake quinnat	.253	.159	.495
Sea quinnat	.242	.143	.545

In the head-standard length ratio the sockeye agree closely with the lake quinnat, but reference to Table 5 will show that the two specimens differ greatly in this proportion, and suggest that the average value would depend largely on the sex composition of the group. The two peduncle proportions of the sockeye come closest to those of the sea quinnat and do not show the great difference between the sexes that is manifest in the head-standard length ratio. If these

sockeye are lake-grown, as appears most likely, it seems strange that they show no indication of the lengthened caudal peduncle so characteristic of lake-dwelling *Oncorhynchus tshawytscha* and lake-dwelling *Salmo salar*.

Acknowledgments

I express my thanks to Mr P. Bayn, manager of Huxley, for much assistance in collecting in the Lake Ohau area, to the Waitaki Acclimatisation Society for bringing down and preserving the two specimens of sockeye from Lake Ohau, and to Dr W. E. Ricker, of the Fisheries Research Board of Canada, and Dr J. C. Briggs, of the University of British Columbia for literature and general information.

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